

**THE *NEOPERLA CLYMENE* (NEWMAN) COMPLEX (PLECOPTERA:
PERLIDAE) IN ILLINOIS, NEW STATE RECORDS, DISTRIBUTIONS, AND
AN IDENTIFICATION KEY**

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Abstract.—Stoneflies of the *Neoperla clymene* (Newman) species complex in Illinois were reexamined from museum and newly collected adult material. Seven species have historically been present in the state. The previously known species, *N. clymene*, is joined by six new state records including *N. catharae* Stark and Baumann, *N. harpi* Ernst and Stewart, *N. mainensis* Banks, *N. occipitalis* (Pictet), *N. robisoni* Poulton and Stewart, and *N. stewarti* Stark and Baumann. Four species (*N. mainensis*, *N. occipitalis*, *N. robisoni*, and *N. stewarti*) are considered extirpated since all records predate 1930. Two species (*N. catharae* and *N. clymene*) have had extensive range reductions, while *N. harpi* has maintained its historical distribution in the state. Large rivers at the periphery of Illinois and small streams in the Shawnee Hills of southern Illinois still maintain populations of *Neoperla*.

Key Words: Plecoptera, *Neoperla*, Illinois, identification key, extirpation

Neoperla in the Nearctic Region were viewed until recently as a single, wide-ranging and variable species, *Neoperla clymene* (Newman) (Stark 1990). Stark and Baumann (1978), Stark and Lentz (1988), and Ernst et al. (1986) split this complex into two species groups, *clymene* and *choc-taw*, based on adult genitalic and egg structures, with 12 recognized species. Subsequent researchers (Ernst et al. 1986, Stark 1995, Smith and Stark 1998) have described three new species to bring the current North American total to 15.

Neoperla reside in relatively clean streams throughout the eastern half of North America (Stewart and Stark 1988). Vaught and Stewart (1974) found that *N. clymene* exhibited a univoltine-slow (no egg diapause) life cycle, while Ernst and Stewart (1985) recorded a late emergence

for *Neoperla* spp. compared to other cohabitating perlids and a preference for trees as adult habitat. These life history attributes leave them susceptible to changes in local stream health including increases in summer water temperature, reduction in dissolved oxygen, increased imbeddedness of mineral substrates, and removal of natural riparian vegetation.

The Illinois Natural History Survey (INHS) established natural history collections late in the nineteenth century as a repository to document the fauna and flora of Illinois, the Midwest, and across the continent. The age of these collections makes them irreplaceable as documentation of the natural communities found before major degradation of the native landform took place. This is fortunate since extinctions, local and regional extirpations, and shrink-

Table 1. Spatial accuracy codes used for *Neoperla* localities in Illinois (Figs. 1–4).

Spatial Accuracy Code	Location Description from Labels
1	Known exact location
2	Small municipality (<50,000 population) or park, point usually placed at center of town or at waterfront if stream name included on label.
3	Land survey data (principal meridian, township, range, section) or large municipality (>50,000), taken as center of municipality or section.
4	County, plotted as center of county.

age of historical range are common responses of stonefly species across the continent.

Frison (1935) investigated the Illinois stonefly fauna for over two decades early in the twentieth century. Many sites were repeatedly visited and their stonefly assemblage was well documented. Among these collections are sufficient numbers of *Neoperla*, then identified exclusively as *N. clymene*, to accurately document the original species assemblage of this environmentally sensitive genus. Reevaluation of this material has recently been completed and the results presented herein. The objective of this study is to document the species of *Neoperla* present in Illinois. We hope, through providing a fully illustrated key to adults and eggs of regional species, that others locate additional populations of this environmentally sensitive genus. This study is part of a larger effort to update Frison’s (1935) *The Stoneflies, or Plecoptera, of Illinois* over 60 years after its publication.

METHODS

Illinois *Neoperla* in the INHS insect collection were reevaluated using current literature. The task of tracking information about each specimen was simplified by a recently completed Plecoptera database that links species names, label data, and location information with a catalogue number. This database is now available in simplified form on the Internet (URL: www.inhs.uiuc.edu/cbd/EPT/index.html).

Poulton and Stewart (1991) reared and associated nymphs of six of seven Interior

Highlands species. However, there are still eight species whose nymphs are either undescribed or inadequately known. Until further associations have been completed, the adults are necessary to definitively identify species in the complex. The tergal process, paraproct, and internal aedeagus are useful for identification of males. Relative length and degree of sclerotization of the spermathecum and the ornamentation of the egg chorion are important female characteristics.

Adult internal structures were viewed by clipping the abdomen from the body at about the fourth segment, then placing it in boiling 10% KOH until clear. Eggs were extracted before boiling and viewed using a compound microscope. In addition to the historical material, new specimens were obtained by rearing of nymphs, ultra-violet light trapping, and by sweeping streamside vegetation from many locations across the state.

Latitude and longitude coordinates for each unique location were recorded from a digital DeLorme® Street Atlas USA. Many records had vague localities, the exact locations of which were impossible to determine. So as not to lose any location data, locations were coded one through four for accuracy (Table 1). This accuracy was denoted on range maps as different sized symbols, usually with closed points and open circles of increasing size. Collection locations were stored in electronic format using FileMakerPro® software. Mapping of these locations was produced using ArcView® software.

Traditionally, location information has been provided in the text of works such as these. We have opted to rely on the Plecoptera database web site for dissemination of this detailed and highly repetitive information. Those who do not have access to the Internet may request the information from the senior author in other formats.

RESULTS

Adult *Neoperla* accounted for 92 of the current 4,880 Illinois and 18,885 total Plecoptera records at the INHS (Table 2). A total of 411 adult specimens was reevaluated that represented 32 unique historical and contemporary locations (Fig. 1). Seven of the 15 species in the genus are now known to occur in Illinois (Table 2). Six belong to the *clymene* species group, while one belongs to the *choctaw* group. Six of these species are new state records and some represent sizable range extensions. The greatest concentration of both species and specimens were from the state's southern tip where stream gradients were high and overall stream health best. Despite the large range in latitude, 37.00° to 42.16°N, the majority of records indicated a mid-June through late July emergence for all species encountered. Illinois distributions, brief notes on general ecological requirements, and additional information on taxonomic characters are provided for each species.

Neoperla catharae Stark and Baumann (Figs. 3, 5, 12)

This species provided 7.6% of Illinois *Neoperla* records and 2.7% of all specimens (Table 2). This is the only member of the *N. choctaw* Stark and Baumann species group to be taken in Illinois. Its presence is a new state record. Historically, specimens were taken as far north as Champaign County, in the headwaters of the Embarras and Vermilion rivers (Fig. 3). The exact collection location has been coded with an accuracy code of two, which straddled streams in both drainages. All populations

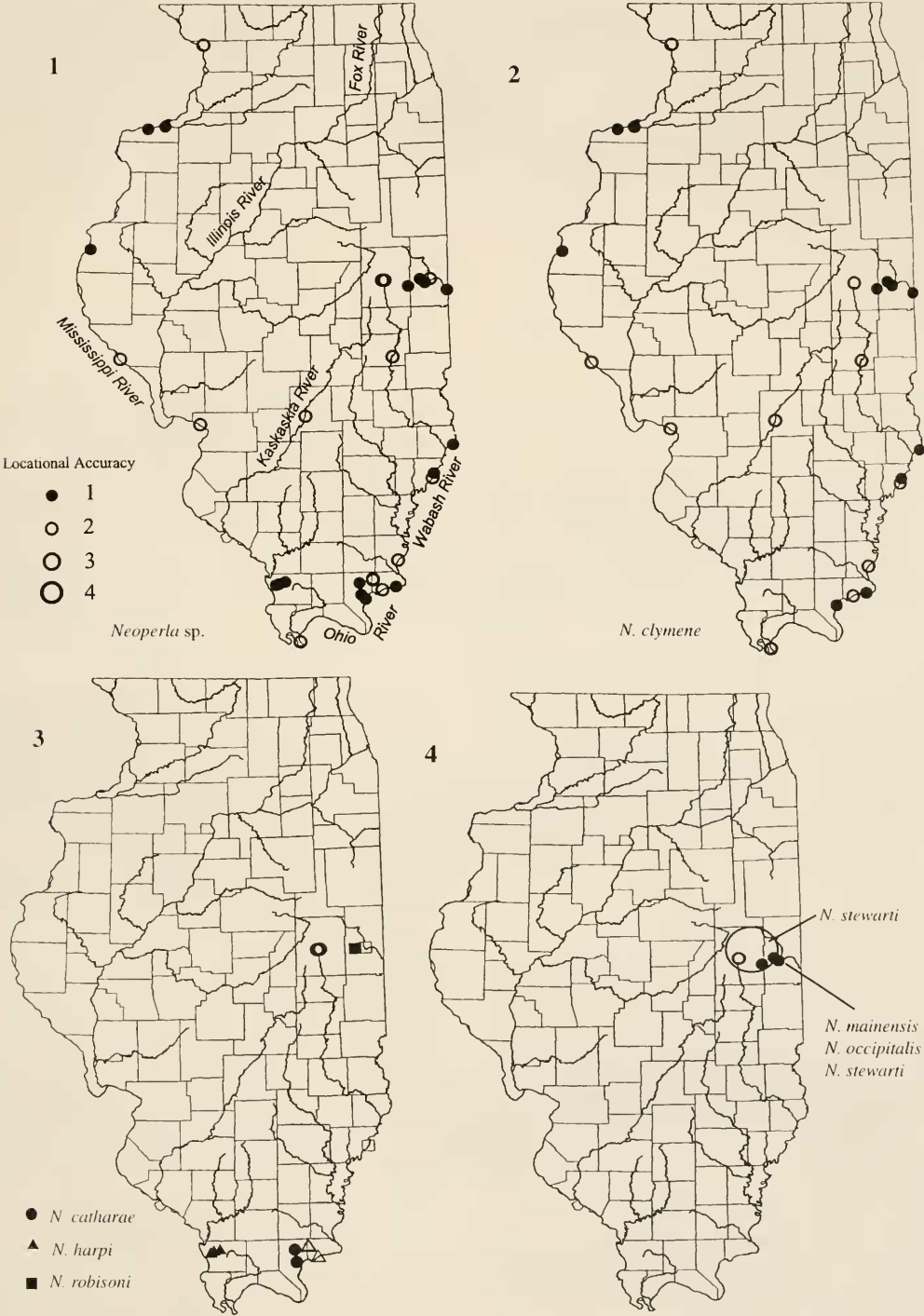
in the central Illinois Grand Prairie natural division (Schwegman 1973) appear to have been extirpated since no specimens have been taken since 1889.

Extant populations survive only in high quality streams in the Lusk Creek drainage of southern Illinois. The Shawnee National Forest buffers this area from agriculture and other development; therefore, the species is afforded some measure of protection against water quality degradation. Other populations may eventually be found further west in similar uplands of the Ozark Hills natural division along the Mississippi River. Its current range includes Alabama, Arkansas, Kentucky, Missouri, Ohio, Oklahoma, Pennsylvania, Tennessee, and Virginia (www.mc.edu/~stark/stonefly.html). No detailed life history information is available for this species (Stewart and Stark 1988). Ernst and Stewart (1985) found that it emerged later than its congeners, August through September, with males and females having negatively skewed and extended emergence patterns, respectively.

Neoperla clymene (Newman) (Figs. 2, 6, 13)

Harris and Webb (1995) listed this species from Illinois. *Neoperla clymene* provided 35.9% of the records and 14.4% of the specimens and was the most widely distributed *Neoperla* in Illinois (Table 2, Fig. 2). It was most abundant in larger rivers such as the Wabash, Ohio, and Mississippi rivers, where it was recently common in light trap samples from a reach south of Rock Island. Several specimens were recently taken from the Vermilion River near the Indiana border. These represent the only contemporary specimens from small-to-medium sized rivers throughout middle Illinois (DeWalt et al. 1999).

Historically, the species was abundant in the Embarras, Kaskaskia, and Vermilion rivers (Fig. 3) of the Grand Prairie and Southern Till Plain of central Illinois. Stark (1990) reported it from throughout the



Figs. 1–4. *Neoperla* locations in Illinois. 1, All *Neoperla* locations in Illinois. 2, *N. clymene*. 3, *N. catharae*, *N. harpi*, *N. robisoni*. 4, *N. mainensis*, *N. occipitalis*, *N. stewarti*.

Table 2. *Neoperla* species found, number of adult records in Plecoptera database, number of individuals in INHS insect collection, and the number of unique sites across Illinois from which *Neoperla* species were taken.

Species	Records	Individuals	Unique Sites
<i>Neoperla catharae</i> Stark and Baumann 1978	7	11	4
<i>Neoperla clymene</i> (Newman) 1839	33	59	20
<i>Neoperla harpi</i> Ernst and Stewart 1986	18	235	7
<i>Neoperla mainensis</i> Banks 1948	2	2	1
<i>Neoperla occipitalis</i> (Pictet) 1841	1	1	1
<i>Neoperla robisoni</i> Poulton and Stewart 1986	3	18	3
<i>Neoperla stewarti</i> Stark and Baumann 1978	28	85	4
Total	92	411	32

southeastern United States and indicated that some older eastern and midwestern literature records should be viewed with doubt until specimens have been reexamined. He implied that they might have been confused with a newly named species, *N. osage* Stark and Lentz. Vaught and Stewart (1974) recorded an univoltine-slow life cycle for *N. clymene* in the Brazos River of west central Texas. Ernst and Stewart (1985) reported emergence characteristics for this species, but Stark and Lentz (1988) showed their studied population to be an undescribed species, *N. falayah* Stark and Lentz.

Neoperla harpi Ernst and Stewart
(Figs. 3, 7, 14)

This species is restricted to the southernmost tip of Illinois, in the Shawnee and Ozark Hills natural divisions (Fig. 3). Its presence represents a new state record. Despite representing only 19.6% of the records, it provided a disproportionate share, 57.2%, of the specimens examined. A robust population exists in the Hutchins Creek drainage near Wolf Lake, Illinois. Part of this drainage is protected within the La Rue–Pine Hills Ecological Area, a National Natural Landmark. Historical records also indicate its presence in the Shawnee Hills, farther to the east.

Poulton and Stewart (1991) considered this species an Ozark endemic. Ross (1944) spoke of the Ozark and Shawnee Hills natural divisions as extensions of the Missouri

Ozarks, and therefore, it is not surprising to find this species in southern Illinois. Stark (1990) listed Arkansas, Missouri, and Oklahoma as locations for this species. Poulton and Stewart (1991) collected adults from late May through late August, but no additional life history data are available.

Neoperla mainensis Banks
(Figs. 4, 8, 15)

The species is represented by two records consisting of two females (Table 2) from Frison’s (1935) famous Oakwood, Illinois location on the Salt Fork of the Vermilion River (Fig. 4). *Neoperla mainensis* is the only known member of the *clymene* group that has a notched, triangular subgenital plate, thus, we feel confident in our determination. Its presence in Illinois represents a new state record and a significant range extension from the known localities of Ohio, Maine, and Ontario (Stark 1990). No specimens have been collected since 1927; therefore, we feel that it has been extirpated from Illinois. No life history data are available for this species (Stewart and Stark 1988).

Neoperla occipitalis (Pictet)
(Figs. 4, 9, 16)

This species was taken as a single female (Table 2) from the Oakwood location (Fig. 4). Its presence represents a new state record. It has not been collected since 1925; therefore, it appears to have been extirpated from Illinois. It is known from much of the

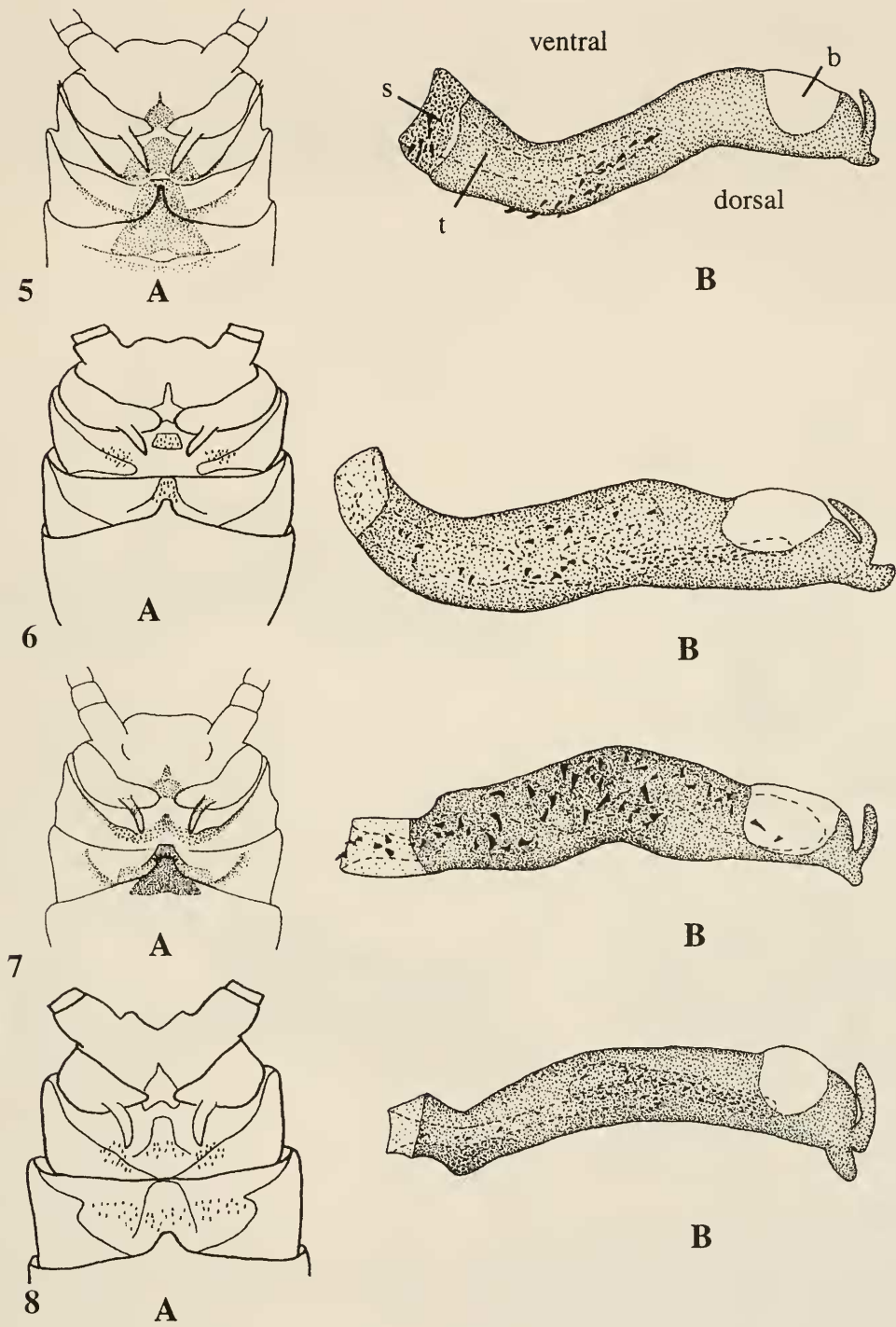


Fig. 5–8. Male structures of *Neoperla* spp. A = abdominal terga 7–10; B = aedeagus, lateral. 5. *N. catharae*. 6. *N. clymene*. 7. *N. harpi*. 8. *N. mainensis*. Abbreviations: b = bulb, t = tube, s = sac. Figures 5A and 7A modified from Poulton and Stewart (1991); Figures 6A and 8A modified from Stark and Baumann (1978).

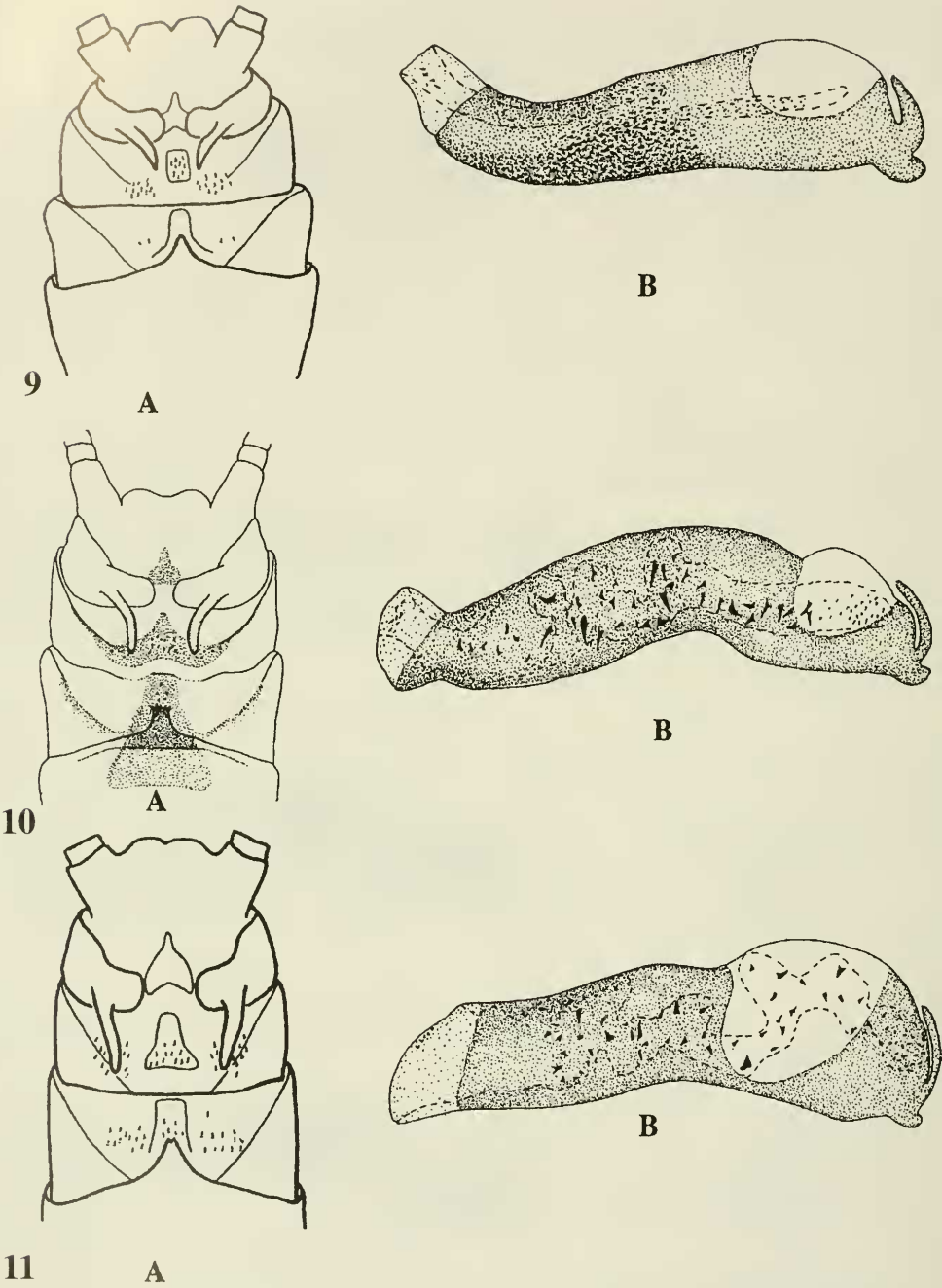


Fig. 9-11. Male structures of *Neoperla* spp. A = abdominal terga 7-10; B = aedeagus, lateral. 9, *N. occipitalis*. 10, *N. robisoni*. 11, *N. stewarti*. Figure 10A modified from Poulton and Stewart (1991); Figures 9A and 11A modified from Stark and Baumann (1978).

Great Lakes region, where it is apparently common, and from as far south as northern Alabama and Mississippi (Stewart and Stark 1988). No life history information is available for this species (Stewart and Stark 1988).

Neoperla robisoni Poulton and Stewart
(Figs. 3, 10, 17)

This species represented 3.3% of records and 4.4% of Illinois *Neoperla* specimens (Table 2). Its presence constitutes a new state record, but since it has not been collected since 1939, it is probably extirpated from the state. Historically, this species resided in the Vermilion and Wabash river basins of east central Illinois (Fig. 3). Its published distribution includes Arkansas, Mississippi, Missouri, Oklahoma, and Tennessee (Stark 1990). Stewart et al. (1974) listed *N. clymene* from New Mexico, which was subsequently identified by Stark (1990) as *N. robisoni*. Stark (1990) has raised doubt as to the validity of the label data associated with any *Neoperla* specimens found in New Mexico. Poulton and Stewart (1991) and Ernst et al. (1986) found that *N. robisoni* primarily inhabited Gulf Coastal Plains streams, emerging in late May and through June. No detailed life history data are available for this species (Stewart and Stark 1988).

Neoperla stewarti Stark and Baumann
(Figs. 4, 11, 18)

This species represented 30.4% of records and 20.7% of the individuals (Table 2). It is also a new state record. It has not been collected in Illinois since 1930, and is feared extirpated from the state. Historically, it was locally abundant in the Vermilion River drainage of eastern Illinois (Fig. 4). Previous records are for Alabama, Kentucky, Maine, Minnesota, Mississippi, Ohio, Pennsylvania, Tennessee, Virginia, and Wisconsin (Stark 1990).

Difficulty in identification may arise with some females due to the presence of a parasitoid wasp, the pupa of which usually de-

velops in the spermathecum. Distortion of this organ gives the mistaken appearance of a *choctaw* complex species by darkening and expanding the very tip of the spermathecum. Parasitism rates ranging from 10 to 50% were observed. The pupa was large enough to completely block the spermathecum and questions the efficacy of mating for afflicted specimens. No life history data are available for this species (Stewart and Stark 1988).

DISCUSSION

The number of stonefly species known from Illinois has changed considerably since Harris and Webb (1995) published an updated nomenclature and listed 63 species for the state. DeWalt and Stark described *Perlesta golconda* (in DeWalt et al. 1998) and DeWalt et al. (2001) added six state record *Perlesta* species for a new total of 70. The addition of the new *Neoperla* species brings the total to 76 species.

The perlid stonefly genus *Perlesta* was found to contain at least eight species in Illinois (DeWalt et al. 2001). These species appear to be relatively unaffected by the large-scale anthropogenic disturbance of the Illinois landscape. In fact, one species has moved into Illinois over the past three decades. A rather different scenario has unfolded for *Neoperla* species. It appears that four of the seven species now known from the state, have been extirpated (*N. mainensis*, *N. occipitalis*, *N. robisoni*, and *N. stewarti*). Additionally, two have experienced apparent range reductions (*N. clymene* and *N. catharae*), while only one (*N. harpi*) appears to have maintained its historical range.

This differential response to changes in the Illinois landscape is intriguing. *Neoperla* typically reside in relatively clean streams in Illinois and in the Interior Highlands (Poulton and Stewart 1991). Hilsenhoff (1987) and Lentz (1993) have provided pollution tolerance values that rank *Neoperla* as highly sensitive to environmental degradation. *Neoperla clymene* exhibits an

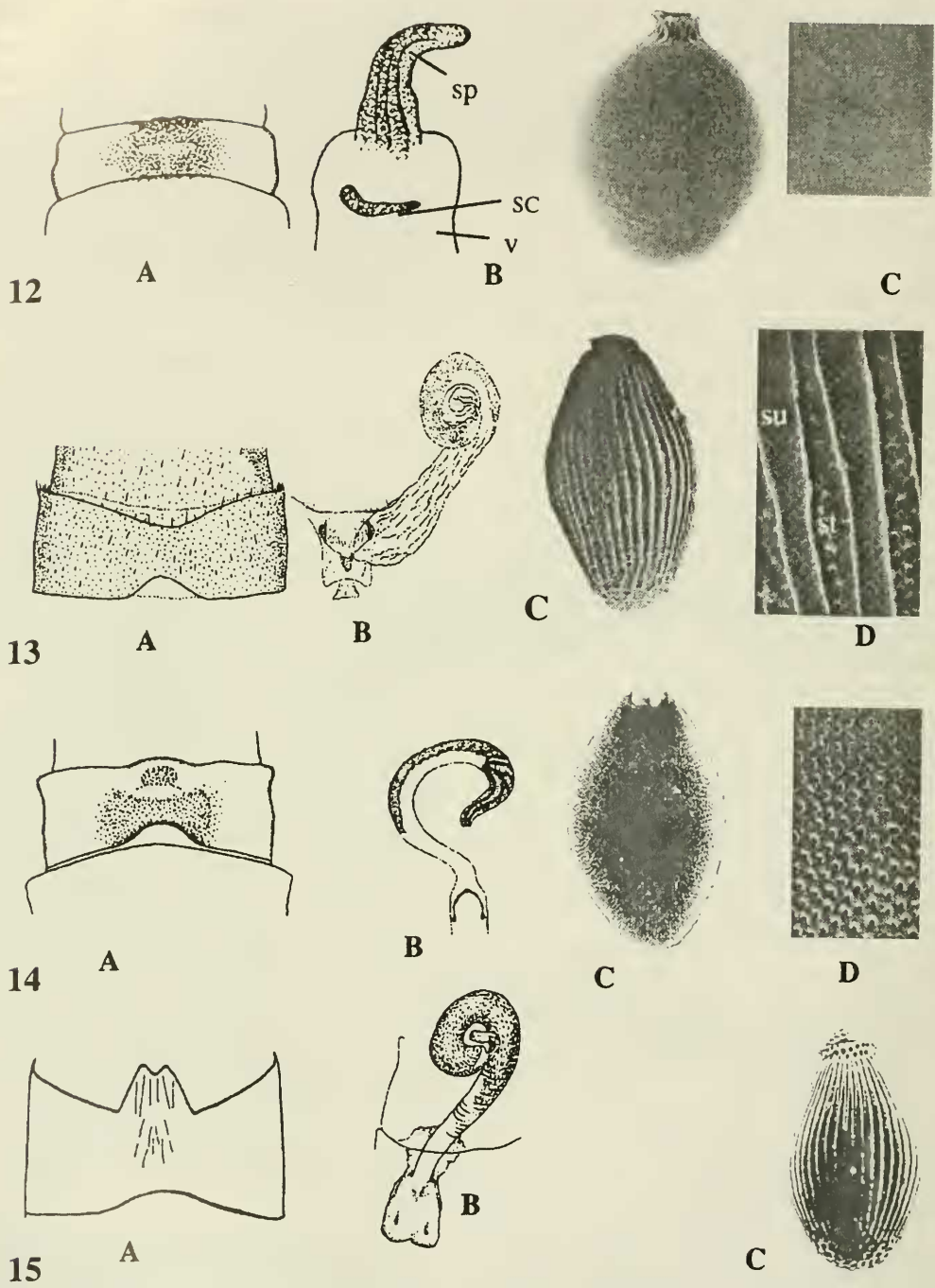


Fig. 12–15. Female and egg structures of *Neoperla* spp. A = abdominal sternite 8 and subgenital plate; B = spermathecum; C = egg; D = detail of egg chorion. 12, *N. catharae*. 13, *N. clynene*. 14, *N. harpi*. 15, *N. mainensis*. Abbreviations: sc = sclerite, sp = spermathecum, str = striae, su = sulci, v = vagina. Figures 12A, 12B, 14A, and 14B modified from Poulton and Stewart (1991); 13A–D from Stark (1990); 12C and 14C from Ernst et al. (1986); and 15A and 15C from Stark and Baumann (1978).

univoltine-slow life cycle, eggs hatch soon after being laid, and nymphs grow throughout the majority of the year (Vaught and Stewart 1974). In that study, no egg diapause was present, unlike what has been shown for *Perlesta decipiens* (Walsh) (Snellen and Stewart 1979). Diapause presumably permits this species to carry the generation through poor environmental conditions such as high summer water temperatures, low dissolved oxygen, or intermittent flow. The presumed lack of diapause in the rest of *Neoperla* species, and any other stonefly with a similar life history, would make them highly susceptible to changes in local land use including stream channelization and removal of riparian trees. This very scenario has taken place in streams across the rich fertile prairies of Illinois, where most of the species' loss and range reductions have taken place for *Neoperla*. It is doubtful that the extirpated species will again live in Illinois streams within the near future. The 'islands' of suitable habitat from which recolonization could occur, even if the conditions of streams in the state were to improve dramatically, are so distant that the species may not bridge the gap. The kind of stream habitat fragmentation that exists in Illinois, and elsewhere in the Midwest, puts the healthy islands at risk of high extinction rates and limits rates of emigration (Zwick 1992). Thankfully, some protection is afforded to those remaining populations of *Neoperla* in southern Illinois, since much of the land is in the Shawnee National Forest.

To facilitate identification of *Neoperla* in Illinois and neighboring states, a key to adults and eggs of the seven known species is provided. This key is modified from Poulton and Stewart (1991) and Stark and Lentz (1988).

KEY TO ADULTS AND EGGS OF ILLINOIS
NEOPERLA

- 1. Male aedeagal tube with external spines (Fig. 5B); anterior margin of female sternum 8 en-

- tire (Fig. 12A); female spermathecum short, not coiled (Fig. 12B); egg chorion smooth (Fig. 12C) *N. catharae*
- Aedeagal tube without external spines (Fig. 6B); female sternum 8 with rectangular, triangular, or sub-circular indentation along anterior margin (Fig. 13A); female spermathecum long, atleast partially coiled (Fig. 13B); egg striate or punctate (Fig. 13C, 14C); *Neoperla clymene* group 2
- 2. Tergum 10 with anteriorly directed genital hooks (Fig. 6A), males 3
- Tergum 10 without genital hooks, females 8
- 3. Aedeagal tube abruptly bent ventrad near midlength (Fig. 7B) 4
- Aedeagal tube straight or slightly sinuate without abrupt bend at midlength (Fig. 6B) 5
- 4. Aedeagal tube apex abruptly constricted (Fig. 7B) *N. harpi*
- Aedeagal tube apex as wide as or wider than subapical area (Fig. 10B) *N. robisoni*
- 5. Aedeagal tube short and plump, length about 3× width at bulb (Fig. 11B) *N. stewarti*
- Aedeagal tube slender, length about 4–6× width at bulb (Fig. 6B) 6
- 6. Aedeagal tube apex with prominent knob (Fig. 8B) *N. mainensis*
- Aedeagal tube apex without knob (Fig. 6B) 7
- 7. Dorsal midlength of tube with prominent patch of spicules, sac armed with very small spines (Fig. 9B) *N. occipitalis*
- Dorsal midlength of tube without prominent patch of spicules, sac with large spines (Fig. 6B) *N. clymene*
- 8. Posteromesal margin of sternum 8 recessed, not projecting beyond posterolateral margins (Fig. 13A) *N. clymene*
- Posteromesal margin of sternum 8 projecting beyond posterolateral margins (Fig. 14A) 9
- 9. Spermathecal stalk lining forming an irregular, jagged inner margin (Fig. 14B); egg non-striate, but coarsely punctate (Fig. 14C) *N. harpi*
- Spermathecal stalk lining not forming jagged margin (Figs. 17B, 18B); egg striate (Figs. 15C–18C) 10
- 10. Subgenital plate triangular and apically notched (Fig. 15A) *N. mainensis*
- Subgenital plate a small truncate tab or otherwise slightly convex surface, not notched at apex (Figs. 16A–18A) 11
- 11. Setal lining of spermathecum restricted to a small apical patch (Fig. 18B) *N. stewarti*
- Setal lining not restricted to apical patch, usually extends >½ length of spermathecum (Figs. 16B, 17B) 12

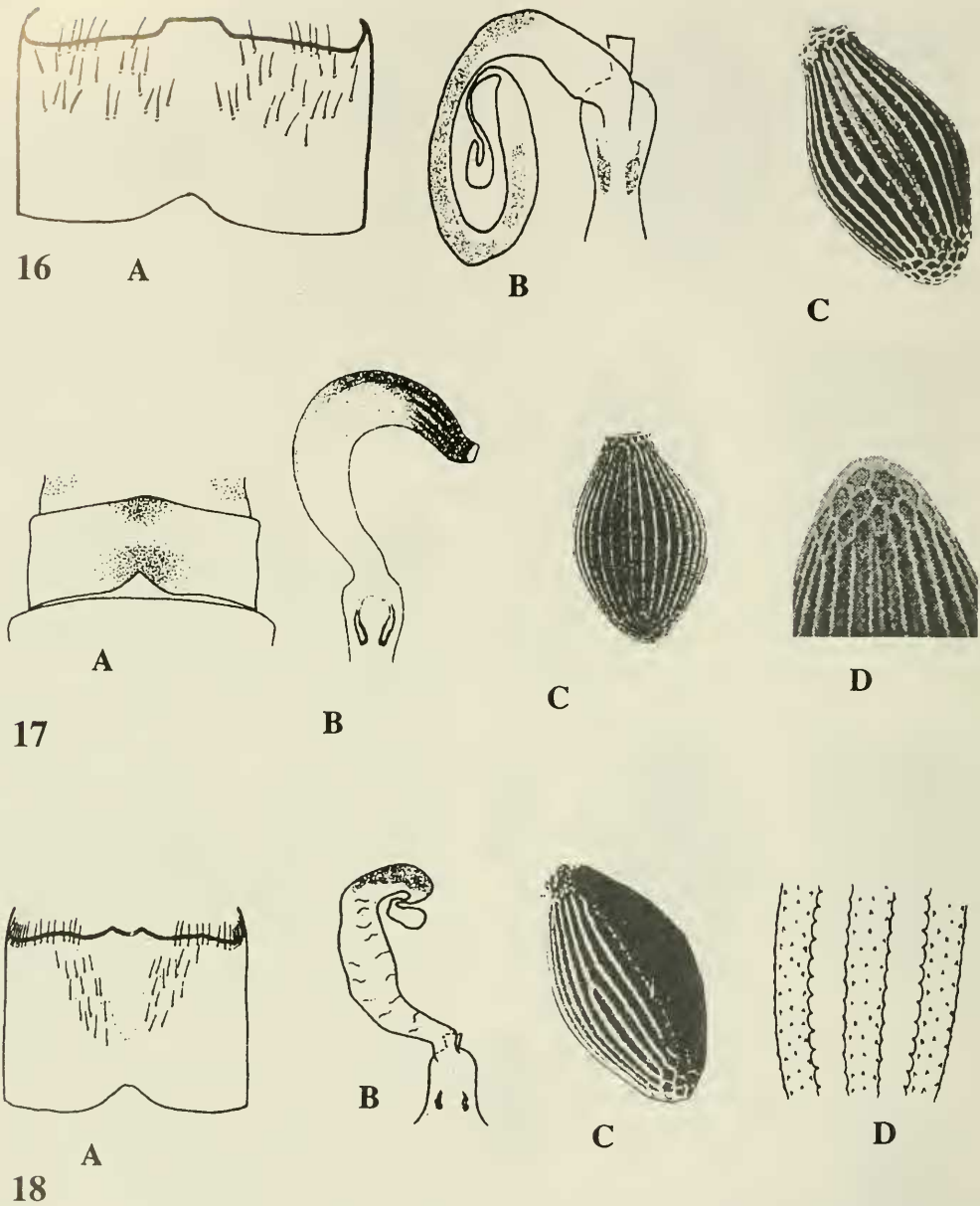


Fig. 16–18. Female and egg structures of *Neoperla* spp. A = abdominal sternite 8 and subgenital plate; B = spermathecum; C = egg; D = detail of egg chorion. 16, *N. occipitalis*. 17, *N. robisoni*. 18, *N. stewarti*. Figures 17A and 17B modified from Poulton and Stewart (1991); 17C and 17D from Ernst et al. (1986); and 16A–D and 18A–C from Stark and Baumann (1978).

- 12. Spermathecal stalk lining tapered to a rounded apex and without darkened longitudinal ridges (Fig. 16B) *N. occipitalis*
- Spermathecal stalk lining truncate apically and with 2–3 folds forming dark longitudinal ridges (Fig. 17B) *N. robisoni*

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